

1 We claim:

1 1. An apparatus, comprising:

2 a monolithic device, the monolithic device comprising;

3 a first CMOS imaging array; and

4 a dark current monitoring device integrated with the first CMOS imaging array, the dark current  
5 monitoring device monitoring the dark current during the time that the first CMOS  
6 imaging array is receiving an image.

1 2. The apparatus of claim 1, where the monolithic device consists of a single semiconductor  
2 chip comprising a silicon substrate with integrated circuitry integrated with a surface of  
3 the silicon substrate.

1 3. The apparatus of claim 1, where the monolithic device consists of a single semiconductor  
2 chip comprising a substrate with integrated circuitry integrated with a surface of the  
3 substrate comprising silicon germanium material.

1 4. The apparatus of claim 1, where the dark current monitoring device is at least one  
2 semiconductor light sensor integrated with the monolithic device having a means attached  
3 to the monolithic device to prevent light from activating the semiconductor light sensor.

1 5. The apparatus of claim 4, where multiple semiconductor light sensors are used to determine  
2 dark current variation over the monolithic device.

1 6. The apparatus of claim 4, where the at least one semiconductor light sensor is a second  
2 CMOS imaging array.

1 7. The apparatus of claim 6, where multiple CMOS imaging arrays are used to determine dark  
2 current variation over the monolithic device.

1 8. The apparatus of claim 1, where the dark current monitoring device comprises;  
2 at least one temperature monitoring device for monitoring temperature of the monolithic device,  
3 and;

4 associated circuitry to determine dark current from the monitored temperature.

1 9. The apparatus of claim 8, where multiple temperature monitoring devices are used to  
2 determine dark current variation over the monolithic device.

1 10. The apparatus of claim 8, where the at least one temperature monitoring device is a PTAT  
2 circuit integrated with the monolithic device.

1 11. The apparatus of claim 8, where the at least one temperature monitoring device is a device  
2 monitoring the voltage drop across a P-N diode junction having a constant current.

1 12. The apparatus of claim 8, where the associated circuitry is integrated with the monolithic  
2 device to determine dark current from the monitored temperature

1 13. The apparatus of claim 1, further comprising;  
2 a stored record of dark current from each pixel of the first CMOS image array, measured  
3 previous to the time that the first CMOS image array receiving the image;

4 associated circuitry using the stored record and the monitored dark current to correct the output  
5 of each pixel of the first CMOS image array.

1 14. The apparatus of claim 13, where the stored record and the associated circuitry using the  
2 stored record are integrated with the monolithic device.

1 15. A method of recording an image of an object using light reflected or transilluminated from  
2 the object, comprising;

3 forming an image of the object on a first CMOS image array by projecting the light reflected or  
4 transilluminated from the object on to the first CMOS image array, the first CMOS  
5 image array formed on a monolithic semiconductor substrate; and

6 monitoring the dark current of the first CMOS image array with at least one dark current  
7 monitoring device integrated with the first CMOS imaging array on the monolithic  
8 semiconductor substrate, the monitoring of the dark current concurrent with the forming  
9 of the image.

1 16. The method of claim 15, further comprising;  
2 recording an output from the first monolithic CMOS image array; and  
3 correcting the output from the first monolithic CMOS image array to account for the dark current  
4 monitored by the at least one dark current monitoring device.

1 17. The method of claim 16, wherein the step of correcting comprises;  
2 recording (a) an output of the at least one dark current monitoring device and (b) the dark current  
3 output from each pixel of the unilluminated first CMOS image array in a different step  
4 than the step of forming the image;

5 calculating the dark current contribution at each pixel during the forming of the image on the  
6 basis of the dark current monitored concurrently with forming the image; and

7 subtracting the dark current contribution at each pixel from the output of the first monolithic  
8 CMOS image array.

1 18. The method of claim 16, wherein the step of correcting is performed by circuitry integrated  
2 on the monolithic semiconductor substrate.

1 19. The method of claim 15, wherein the step of monitoring the dark current comprises;  
2 monitoring the temperature of the first monolithic CMOS imaging array with at least one  
3 temperature monitoring device integrated with the first monolithic CMOS imaging array;  
4 and  
5 calculating the dark current from the monitored temperature.

6  
7 20. The method of claim 19, wherein the step of monitoring temperature comprises;  
8 monitoring the temperature at a plurality of locations on the monolithic semiconductor substrate;  
9 and  
10 calculating the temperature variation over the first CMOS image array during the forming of the  
11 image.

1 21. The method of claim 15, wherein the step of monitoring the dark current comprises;  
2 monitoring the dark current at a plurality of locations on the monolithic semiconductor substrate;  
3 and  
4 calculating the variation of dark current over the first CMOS image array during the forming of  
5 an image of the object.

1 22. The method of claim 15, further comprising;

2 a) exposing the first CMOS image array for a time  $t_s$ , where  $t_s$  is a short enough time that dark  
3 current and projected light produce signals small compared to offset signals in pixels of  
4 the first CMOS array; and then

- 5 b) recording signals  $O_i$  measured as a result of exposure for time  $t_s$ ; and then
- 6 c) subtracting  $O_i$  from signals produced by the first CMOS image array when exposure times are
- 7 long enough that dark current signals are not small compared with  $O_i$ .

1 23. The method of claim 22, wherein the dark current signals of step c) are produced from an

2 unilluminated first CMOS image array, and further comprising;

- 3 d) recording signals  $S_d = G_i (f_i(T, t))$  which result from step c).

1 24. The method of claim 23, further comprising;

- 2 e) projecting light from a uniformly reflecting extended object on to the first CMOS array, the
- 3 light intensity high enough that dark current signals are small compared to signals produced by
- 4 the light illumination; and

- 5 f) recording signals  $S_i = G_i (k_i I_i R_i QE_i) + O_i$  from the first CMOS array produced by light
- 6 projected from the uniformly reflecting object; then

- 7 g) subtracting  $O_i$  from the results of step f);

- 8 h) recording an effective gain coefficient  $G_i^* = G_i (k_i I_i QE_i)$ .

1 25. The method of claim 24, wherein;

2 the step of forming an image of the object comprises recording signals

- 3  $S_i = G_i^* R_i + O_i + G_i f_i(T, t)$  from the first CMOS array; further comprising;

- 4 i) correcting the recorded values  $S_d$  to calculate  $G_i f_i(T, t)$ , wherein the results of the step of

5 monitoring the dark current are used to correct the recorded values  $S_d$ ; and

6 j) calculating  $R_i$  from the known values of  $S_i$ ,  $G_i^*$ ,  $O_i$  and  $G_i f_i(T, t)$ .

1 26. A system, comprising:

2 a monolithic device, the monolithic device comprising;

3 a first CMOS imaging array; and

4 a dark current monitoring device integrated with the first CMOS imaging array, the dark  
5 current monitoring device monitoring dark current concurrently with the recording of an image  
6 by the first CMOS imaging array;

7 an optical system for imaging light reflected or transilluminated from an object on to the first  
8 CMOS imaging array; and

9  
10 circuitry for correcting the output from the first monolithic CMOS image array to account for the  
11 dark current monitored by the dark current monitoring device.

1 27. The system of claim 26, further comprising a storage device for storing the corrected  
2 output.

1 28. The system of claim 27, further comprising a display device for displaying the corrected  
2 output.

1 29. The system of claim 26, wherein the circuitry for correcting the output is integrated on the  
2 monolithic device.

2002/02/08